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NATIONAL DAM SAFETY PROGRAM. ASARCO LAKE DAM (MO 30216), UPPER --ETC(U)
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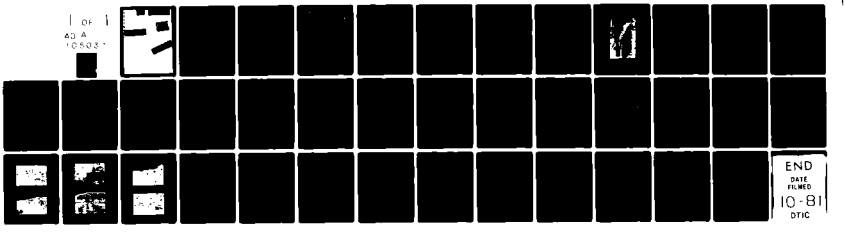

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1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A105 037
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Phase I Dam Inspection Report National Dam Safety Program Asarco Lake Dam (MO 30216) Iron County, Missouri	5. TYPE OF REPORT & PERIOD COVERED Final Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Kenneth Balk and Associates, Inc.	8. CONTRACT OR GRANT NUMBER(s) DACW43-78-C-0169
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	12. REPORT DATE 11 November 1978 13. NUMBER OF PAGES Approximately 30
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

National Dam Safety Program. Asarco Lake Dam (MO 30216), Upper Mississippi - Mississippi - Kaskaskia - St. Louis Basin, Iron County, Missouri. Phase I Inspection Report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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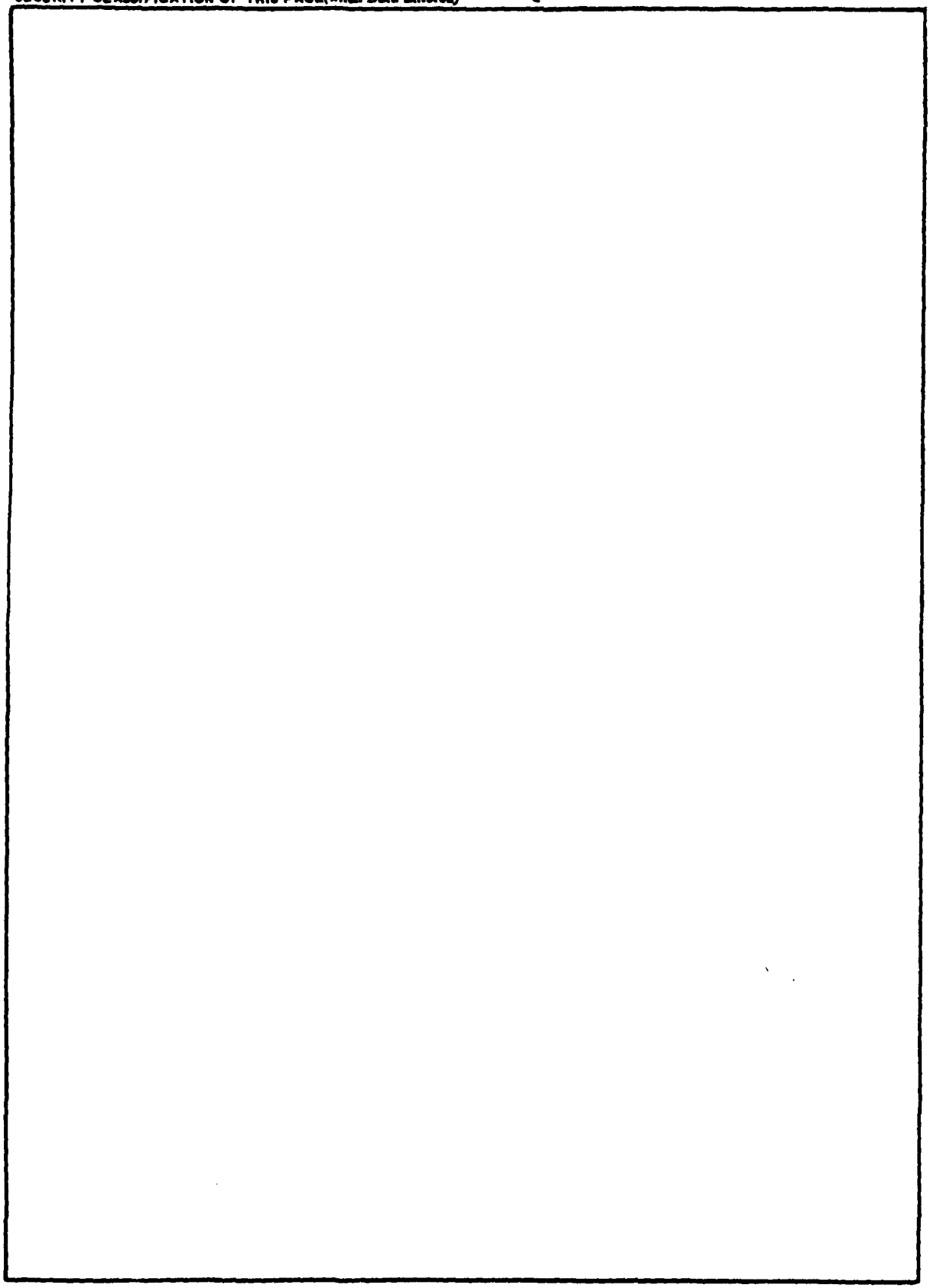

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 NORTH 12TH STREET
ST. LOUIS, MISSOURI 63101

IN REPLY REFER TO

SUBJECT: Asarco Lake Dam Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Asarco Lake Dam.

It was prepared under the National Program of Inspection of Non-Federal Dams

This dam has been classified as unsafe, non-emergency by the St. Louis District as a result of the application of the following criteria:

1) Spillway will not pass 50 percent of the Probable Maximum Flood
2) Overtopping could result in dam failure.
3) Dam failure significantly increases the hazard to loss of life downstream

SUBMITTED BY: SIGNED
Chief, Engineering Division

12 MAR 1979
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer

2 MAR 1979
Date

ASARCO LAKE DAM

IRON COUNTY, MISSOURI

MISSOURI INVENTORY NO. 30216

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY

Kenneth Balk & Associates, Inc.
St. Louis, Missouri
Shannon & Wilson, Inc.
St. Louis, Missouri

PREPARED FOR

ST. LOUIS DISTRICT, CORPS OF ENGINEERS

NOVEMBER, 1978

ASARCO LAKE DAM

IRON COUNTY, MISSOURI

MISSOURI INVENTORY NO. 30216

PHASE I INSPECTION REPORT
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NOVEMBER, 1978

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Asarco
State Located	Missouri
County Located	Iron County
Stream	Tributary To Big Creek
Date of Inspection	August 26, 1978 and September 30, 1978

Asarco Lake Dam, No. 30216 was inspected using the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, U. S. Army, Washington, D.C., with the help of Federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines are considered to represent a consensus of the engineering profession.

Asarco Lake Dam was visually inspected by an interdisciplinary team of engineers from Kenneth Balk & Associates, Inc. and Shannon & Wilson, Inc. The purpose of the inspection was to make a preliminary assessment of the general condition of the dam with respect to safety in order to determine if, in the opinion of the interdisciplinary team, the dam poses recognizable hazards to human life or property. This assessment is based solely upon data made available and visual evidence observed during the site visit.

To make a complete assessment of the safety of the dam would require detailed studies and engineering analyses beyond the scope of this preliminary assessment.

Based on the criteria in the guidelines, the dam is in the high hazard potential classification, which means that loss of life and appreciable property loss could occur in the event of failure of the dam. The estimated damage zone extends five miles downstream of the dam. Two miles downstream of the dam is a smaller lake. Also within the damage zone are a lead smelting plant (one mile from the dam), four homes, one railroad, one highway, and three improved road crossings. Asarco Lake Dam is in the intermediate size classification since it is greater than 40 feet high but less than 100 feet high.

The inspection and evaluation indicate that the spillway of Asarco Lake does not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. Asarco Lake is an intermediate size dam with a high hazard potential, required by the guidelines to pass the PMF. Considering the high hazard potential to loss of life and property downstream of the dam, the outlet facilities of Asarco Lake Dam should be able to pass the PMF without overtopping the dam. However, it was determined that the spillway will only pass approximately 35 percent of the PMF without overtopping the dam.

Since the outlet facilities for Asarco Lake are not capable of passing the PMF without overtopping the dam, the spillway is considered inadequate and the dam is accordingly classified as an unsafe, nonemergency structure.

The evaluation of Asarco Lake also indicated that the spillway will pass the 100-year flood; that is, a flood having a 1 percent chance of being equalled or exceeded during any given year.

In the above evaluations, the effect of a valved, 10 inch diameter regulating pipe was not included. With the 10 inch diameter pipe, set with its springline at a reported elevation of 884.7, an additional discharge of approximately 18.6 cfs (at maximum pool) can be included.

Deficiencies visually observed by the inspection team were some small trees growing in the outlet channel of the emergency overflow spillway. Other deficiencies found were the lack of seepage records, operational records, seepage and stability analyses comparable to the requirements of the Recommended Guidelines, and seismic stability analyses. The lack of stability and seepage analyses on record is a deficiency that should be corrected.

It is recommended that action be taken in the near future to correct or control the deficiencies described.

Ervin H. Baumeyer, P.E.
Principal-In-Charge
Kenneth Balk and Associates, Inc.
St. Louis, Missouri

Lutz Kunze, P.E.
Principal Engineer
Shannon & Wilson, Inc.
St. Louis, Missouri

Overview of Lake and Dam

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
ASARCO DAM - ID NO. 30216

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SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, District Engineer directed that a safety inspection of the Asarco Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon data made available and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed with the help of several Federal agencies and many State agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure built on a tributary to Big Creek in the southern part of Iron County, Missouri. Topography adjacent to the valley is rolling to steep. Most of the area in the vicinity of the dam is covered with a residual silty clay overlying dolomite. Topography in the vicinity of the dam is shown on Plate 1.

(2) The principal spillway consists of a 36" diameter steel drop pipe with trash rack and a 24" diameter steel outlet pipe. An emergency spillway is cut in dolomite on the right abutment (north end of the dam).

(3) A 10 inch diameter pipe, set at a reported springline elevation of 884.7, goes through the dam, with a manually operated valve and stub on the downstream side of the dam. No upstream valve was apparent.

(4) Pertinent physical data are given in paragraph 1.3 below.

b. Location. The dam is located in the southeastern portion of Iron County, Missouri, as shown on Plate 2. The lake formed by the dam is on the Missouri-Iron County Glover quadrangle sheet in the NW 1/4 of Section 2, T32N, R3E.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1c above. Based on these criteria, this dam and impoundment is in the intermediate size category.

d. Hazard Classification. Guidelines for determining hazard classification are presented in the same guidelines as referenced in paragraph c. Based on referenced guidelines, the Corps of Engineers has determined that this dam is in the High Hazard Classification and thus has been selected by the Corps of Engineers for a Phase I inspection.

e. Ownership. The dam is owned by Asarco Inc., Glover, MO.

f. Purpose of Dam. The dam forms an industrial water supply lake.

g. Design and Construction History. There are no known design plans or construction records. According to information supplied by the Corps of Engineers, the dam was completed in 1971.

h. Normal Operating Procedure. No operating records were found. Outflow passes through uncontrolled spillways. Normal rainfall, spillway discharges, runoff, transpiration, and evaporation all combine to maintain a relatively stable water surface elevation.

1.3 PERTINENT DATA

a. Drainage Area - 485 acres.

b. Discharge at Damsite.

(1) 24 inch pipe spillway - 58.8 cfs. at maximum pool.

(2) Emergency spillway - 399.8 cfs at maximum pool.

(3) Estimated experienced maximum flood - approximately two foot below top of dam.

c. Elevation (U.S.G.S.)

(1) Top of dam - 934.0±.

(2) Invert of pipe spillway - 928.7.

(3) Spillway Crest - 928.7.

(4) Streambed at Centerline of Dam - 851.0±.

(5) Maximum tailwater - unknown.

d. Reservoir. Length of maximum pool - 4100 feet ±.

e. Storage (Acre-feet).

(1) Normal - 2055.8.

(2) Maximum - 2412.9.

f. Reservoir Surface (Acres).

(1) Top of dam - 72.

(2) Spillway crest - 62.

g. Dam.

(1) Type - earth embankment.

(2) Length - 700 feet.

(3) Height - 83 feet maximum.

(4) Top width - 18 feet.

(5) Side Slopes - (Measured by slope meter/inclinometer in degrees and converted to ratios.)

(a) Downstream - 2.75 H to 1 V.

(b) Upstream - 2.25 H to 1 V to a 12' wide berm. Visibly flatter below waterline.

(6) Zoning - unknown

(7) Impervious core - unknown

(8) Cutoff - unknown

(9) Grout curtain - unknown

h. Diversion and Regulating Tunnel. 10 inch diameter pipe, reported springline elevation 884.7, with manually operated valve and pipe stub downstream of the dam.

i. Principal Spillway.

(1) Type - 36" diameter steel drop pipe with trash rack and a 24" diameter steel outlet pipe.

(2) Crest elevation - 928.7 U.S.G.S.

j. Emergency Overflow Spillway

(1) Type - Rock channel, generally trapezoidal in section.

(2) Invert at lakeside 932.0 (USGS).

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

No design data were found to be readily available.

2.2 CONSTRUCTION

According to information supplied by the Corps of Engineers, the dam was completed in 1971.

2.3 OPERATION

No records of the maximum loading on the dam were available.

2.4 EVALUATION

a. Availability. No engineering data were readily available. A geologic report by the Missouri Geological Survey was available and was considered in preparation of the report.

b. Adequacy. No engineering data was made available to make a detailed assessment of the design, construction, and operation. The lack of seepage and stability analyses comparable to the requirements of the Recommended Guidelines is considered a deficiency which should be corrected. An engineer experienced in the design of dams should be retained to perform detailed seepage and stability analyses.

c. Validity. No valid engineering data on design were made available.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

A. General. A visual inspection of the Asarco Dam was carried out on August 26, and September 30, 1978. Personnel making inspection were employees of Kenneth Balk and Associates, Inc. and Shannon and Wilson, Inc. of St. Louis and included civil, geotechnical, and structural engineers and an engineering geologist. Specific observations are discussed below.

B. Dam. The inspection team observed the following at the dam.

The dam is an earth embankment with a hard-packed earth road along the crest. A small structure, reported to be a water quality monitoring and recording station is located at the west end of the dam. Another small structure, reported to be a chlorination facility, is located a few feet downstream from the toe toward the left abutment.

The upstream embankment slope has a 12 foot wide berm, approximately 5 feet lower than the crest, running the length of the dam. No detrimental settlement, seepage, depressions, animal burrows, slope instability or cracking was observed on or adjacent to the embankment. The slopes were clear of trees and excessive vegetation which is considered evidence of periodic maintenance. Upstream erosion protection consists of a cover of grass. The downstream slope is covered with grass.

The area near the emergency spillway on the right abutment and directly upstream of the monitoring and recording structure is riprapped with large rock and is assumed to be the intake location of the water supply for the Asarco smelter.

C. Appurtenant Structures. The principal spillway, consisting of a 36" diameter steel drop pipe with trash rack and a 24" diameter steel outlet pipe located toward the right or west abutment, and its outlet channel are in good condition. Main spillway discharges would not, in our opinion, endanger the integrity of the dam.

An emergency spillway is cut on the right abutment in moderately hard dolomite. The spillway outlet channel is cut into moderately jointed and hard compact dolomite. Discharge through the emergency spillway presents no problem to the dam's integrity.

Some small trees are growing in the outlet channel beyond a fence, which was assumed to be the property line. This is considered to be a deficiency which should be corrected.

D. Reservoir Area. No wave wash or slides were observed along the shore of the reservoir. Some erosion is evident along the left shore of the lake in the area that was used as a borrow area for the embankment.

E. Damsite Geology.

1. Dam Base: An outcrop 100 feet west of the east abutment projects into the base of the dam and may represent the foundation bedrock underlying the dam. The outcrop consists of 6 inch to 2 foot thick beds of light grey dolomite grainstone showing extensive refilled solution channels. Open solution channels also occur sporadically along and vertically across bedding. Maximum channel thicknesses are about an inch and of very limited extent horizontally or vertically.

2. Right Abutment: Except near the emergency spillway, the right abutment is covered with a thin blanket of residual silty clay containing abundant residual chert. Near the secondary spillway, outcrops of bedrock continue uphill to a height of 25 feet above the emergency spillway. To avoid duplication, the geology of the abutment and of the emergency spillway are discussed together here.

Dolomite - The visible bedrock of the right abutment consists of 2 to 4 feet thick beds of dominantly medium-grained dolomite (probably Derby-Doerun Formation of the Upper Cambrian Series). The dolomite is light grey to grey-brown with light brown weathering surfaces, and shows extensive healed solution cavities which have refilled with silt and masses of euhedral dolomite crystals (1/16 inch across). Apparent algal mat structures and cut and fill packstone channels are common. Small solution pits, possibly of dissolved anhydrite or gypsum are abundant in some of the beds.

Shale - Local pods and lenses of dominantly green shale occur between dolomite beds. These thin shale lenses form only a small percentage of the bedrock.

Bedding - Bedding dips 1-2^{0} eastward. Bed tops and bottoms are irregular, with no visible permeability along bedding planes; bedding planes are generally poorly developed.

Joints - Only one set of N65-70E striking vertical joints was observed. The joints are poorly developed and uncommon. One joint swarm with 5 inch to several foot spacing has local solution cavities occurring along the otherwise apparently tight joint system. The solution cavities, up to 8 inches across, do not extend more than a few feet horizontally and do not appear to cut vertically across more than one or two beds.

3. Left Abutment: Dolomite beds similar to these described in the right abutment, and probably of the same general geologic section outcrop intermittantly along a ditch next to the access road along the left abutment. These outcrops are limited, but the general description of right abutment geology applies to the left abutment. Except for the limited ditch outcrops of dolomite, the left abutment is covered by reddish silty clay, with abundant residual chert.

3.2 EVALUATION

The inspection team observed no conditions at the dam which require immediate remedial action. The erosion protection on the upstream slope appears adequate for this dam and the few small trees in the emergency spillway outlet channel are considered a minor deficiency which should be corrected.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

A 10 inch diameter steel pipe, set with its springline at a reported elevation of 884.7, extends through the dam with a manually operated valve and pipe stub downstream of the dam. This system can be used to regulate the lake level. Normally, the lake level is affected by rainfall, runoff, evaporation, and the capacity of the uncontrolled spillway.

4.2 MAINTENANCE OF DAM

No maintenance records of the dam were available, however the absence of trees and excessive vegetation suggest that a regular program of vegetation control is probably in existence.

4.3 MAINTENANCE OF OPERATING FACILITIES

No maintenance records were available.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

The inspection team is not aware of any existing warning system for this dam.

4.5 EVALUATION

The location of the valve on the downstream end of the 10 inch diameter steel pipe could lead to internal erosion of the dam in the event of a joint or pipe failure. Consideration should be given to the design and installation of suitable measures to prevent this occurrence in the event of failures noted above.

In our opinion, the owner should keep records of the maintenance performed on this dam.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. There were no hydraulic and hydrological design data available.

b. Experience Data. The drainage area and lake surface area are developed from USGS Glover Mo. Quadrangle, 7.5 minute series, dated 1966. The spillway and dam layout are from surveys made during the inspection.

c. Visual Observations.

(1) The pipe spillway and the outlet, with the exception of a small amount of debris caught on the trash rack, are in good condition. The emergency overflow spillway is located on the north side of the lake and its discharge presents no problem to the dam's integrity.

(2) The principal spillway outlet is located toward the right or west abutment. Spillway discharges, in our opinion, would not endanger the integrity of the dam.

d. Overtopping Potential. The principal and overflow spillways have been found to be inadequate to pass the Probable Maximum Flood (PMF) without overtopping the dam. The probable maximum flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region.

For the PMF, the dam would be overtopped to a maximum height of approximately 2.5 feet with a duration of overtopping of approximately 6.5 hours with a maximum discharge rate of 5534 cfs. In our opinion, failure of the dam may be expected to occur as a result of overtopping for this length of time.

For 50% of the PMF, the dam would be overtopped to a maximum height of approximately 0.9 feet for a duration of approximately 4.1 hours with a maximum discharge rate of approximately 1055 cfs.

The spillways have been found to be adequate to pass a flood of approximately thirty-five percent (35%) of the PMF.

The spillways have been found to be adequate to pass the 100 year flood, which has a 1% chance of being equalled or exceeded at least once during any given year.

The estimated damage zone extends five miles downstream of the dam. Two miles downstream of the dam is a smaller lake. Also within the damage zone are a lead smelting plant (one mile from the dam), four homes, one railroad, one highway and three improved road crossings.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visually observed conditions which can affect the structural stability of this dam have been discussed in Section 3.

b. Design and Construction Data. No design or construction data relating to the structural stability of the dam were found.

c. Operating Records. There is a regulating structure in the lake near the right abutment, however no records were available at the time of the inspection.

d. Post-Construction Changes. No post-construction changes could visually be detected.

e. Seismic Stability. The location of Asarco Dam is in Seismic Zone 2. No engineering data was available to evaluate the seismic stability of the dam, and the effect of an earthquake of the magnitude expected in this zone on a dam of this type and size could not be assessed.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Corrective measures should be taken for the deficiencies visually observed by the inspection team, i.e., growth of trees in the spillway outlet channel. Inadequate spillway capacities are also considered to be a deficiency. Debris blockage of the principal spillway can adversely affect its capacity.

b. Adequacy of Information. No engineering design and construction data was available and the conclusions of this report are based on performance and external visual conditions. A report from the Missouri Geological Survey was available and was considered in the preparation of this report. The inspection team considers that these data are sufficient to support the conclusions herein. Seepage and stability analyses comparable to the requirements of the recommended guidelines (including seismic analyses) were not available and this is considered a deficiency which should be rectified.

7.2 REMEDIAL MEASURES

a. O&M Procedures. The following O&M procedures are recommended:

(1) Trees and excessive vegetation should be removed from the emergency spillway outlet channel.

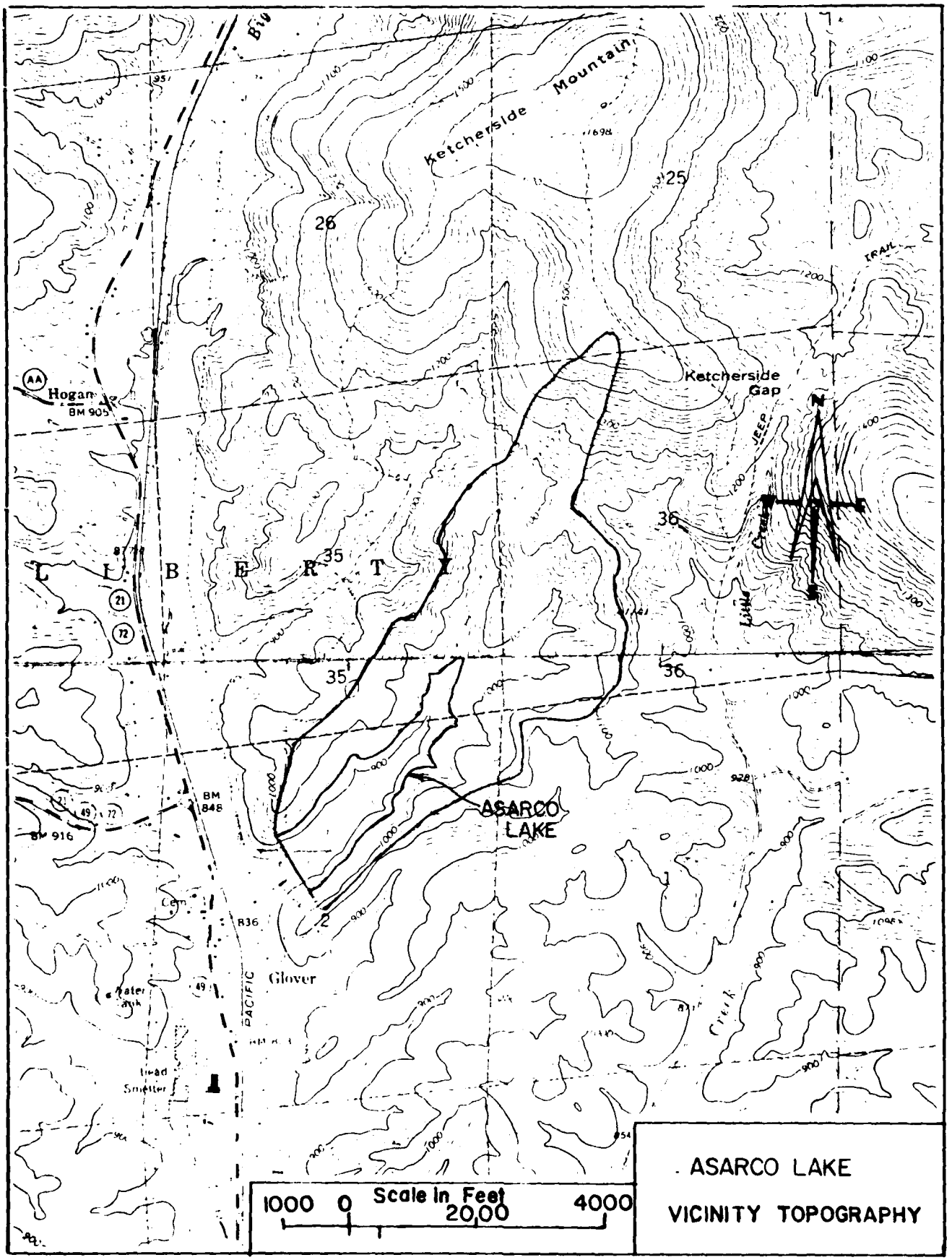
(2) Up-to-date records of all future maintenance and repairs should be kept.

(3) Spillway capacities and/or height of dam should be increased to pass 100 percent (100%) of the Probable Maximum Flood.

(4) Consideration should be given to the design and installation of suitable measures to protect the embankment from internal erosion in the event of a failure of the 10 inch diameter pipe, its joints, or the downstream valve.

(5) Stability and seepage analyses should be performed by a professional engineer experienced in the design and construction of dams.

(6) The dam should be periodically inspected by an Engineer experienced in the design and construction of dams, and records kept of these inspections.



ASARCO LAKE

VICINITY TOPOGRAPHY

PLATE 1

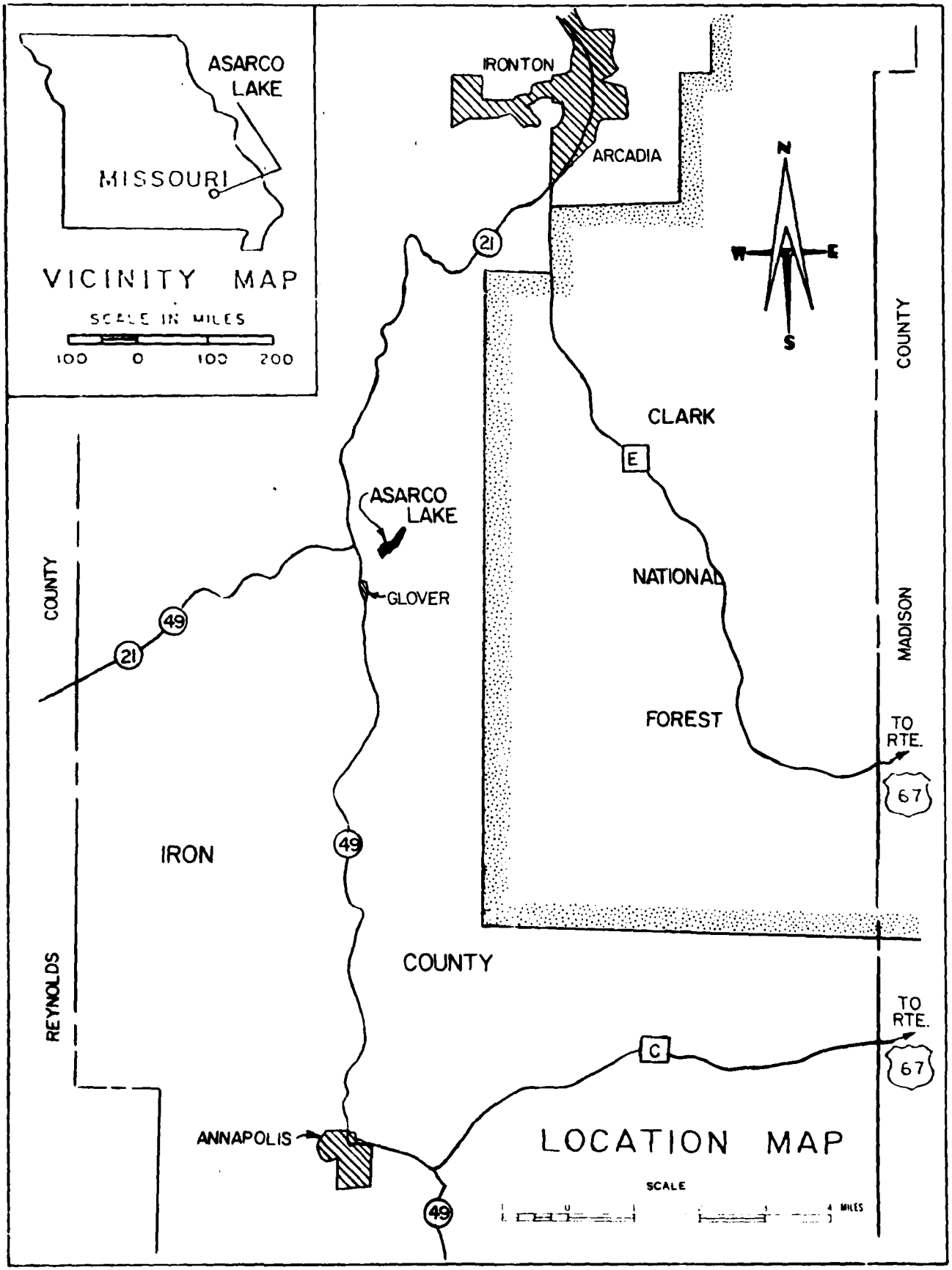
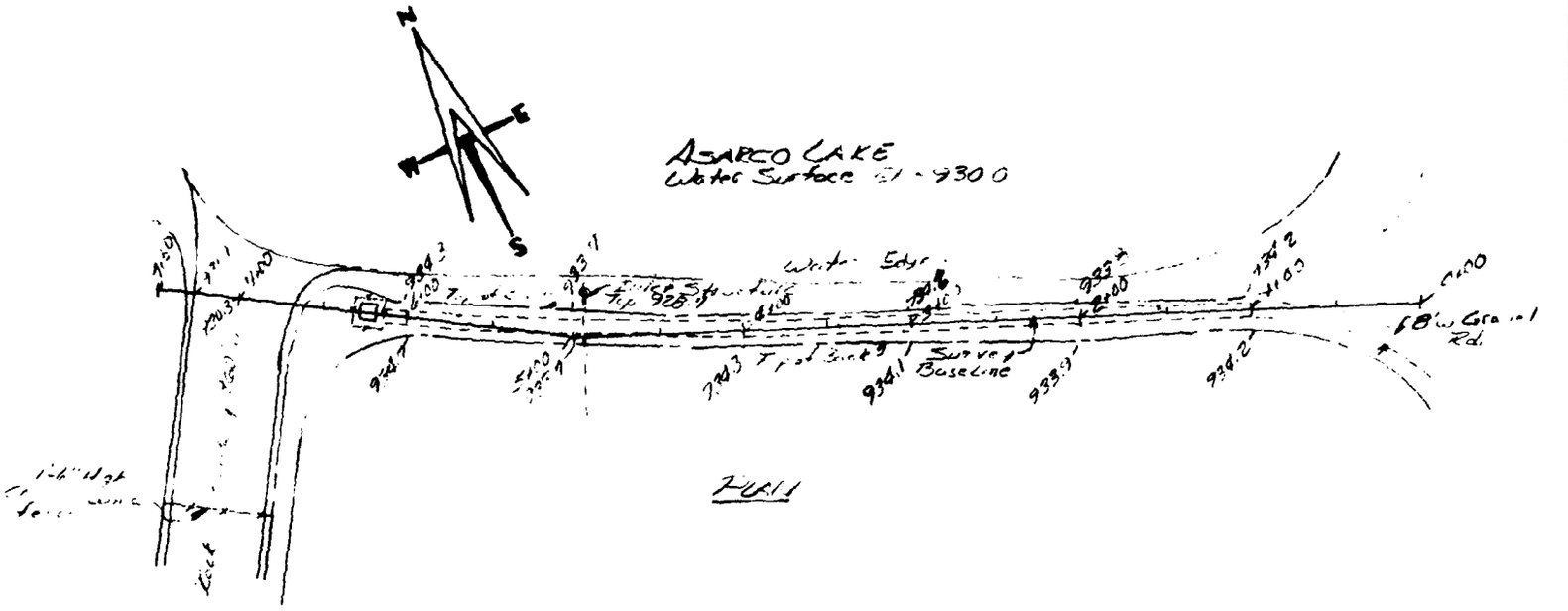

ASARCO LAKE
MISSOURI
VICINITY MAP
SCALE IN MILES
100 0 100 200
IRONTON
ARCADIA
21
N
W
E
S
COUNTY
CLARK
E
ASARCO LAKE
GLOVER
NATIONAL
FOREST
MADISON
COUNTY
49
21
TO RTE.
67
IRON
49
COUNTY
REYNOLDS
TO RTE.
C
67
ANNAPOLIS
49
LOCATION MAP
SCALE
0
1
4 MILES

PLATE 2

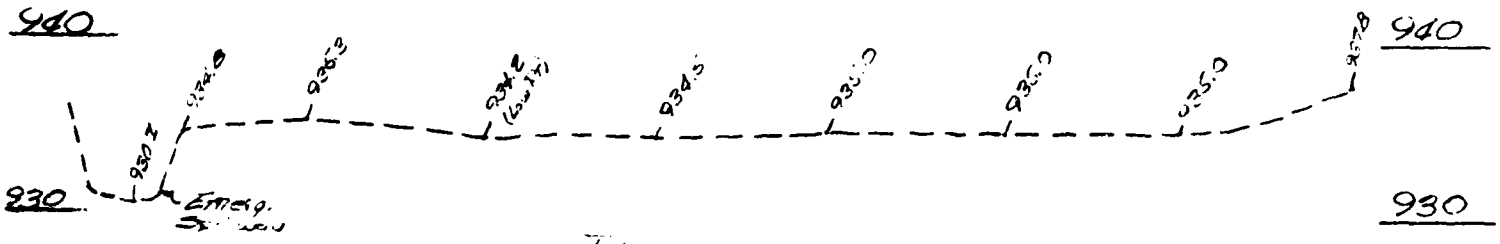


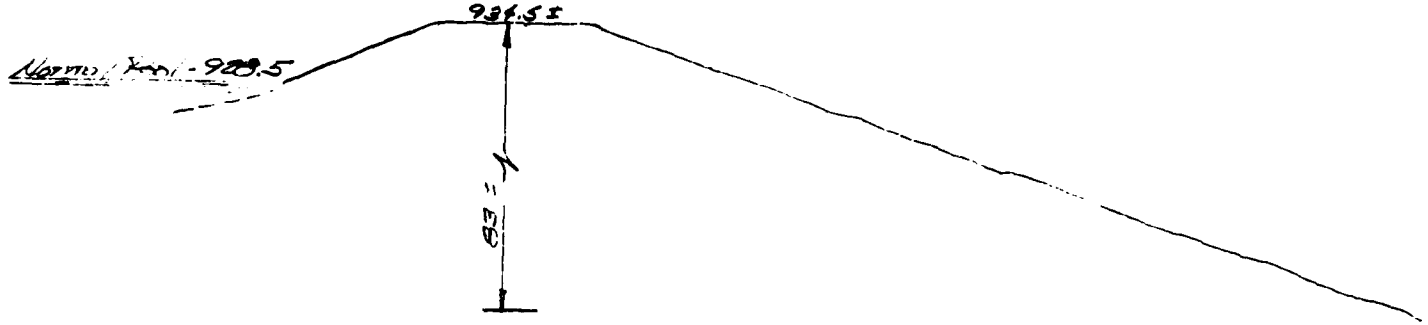
ASARCO LAKE

TOP OF DAM ELEVATIONS

SCALE: 1"=100'

PLATE 3





Typical Cross Section

Scale: 1"=20' Horiz. & Vert.

ASARCO LAKE

DAM PROFILE and
CROSS SECTION

PLATE 4

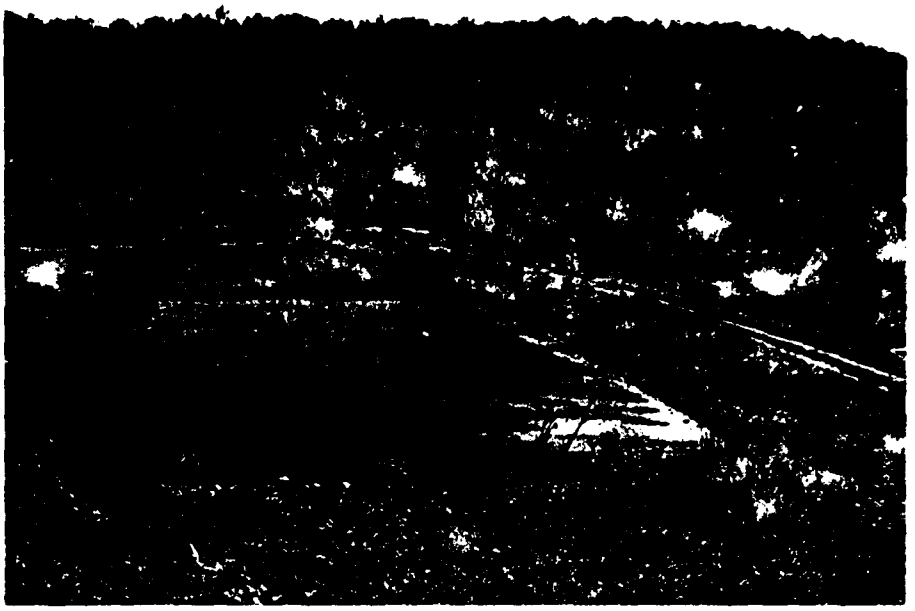


PHOTO 1 Overview of Lake and Dam

PHOTO 2 Borrow Area on Left Shore of Reservoir

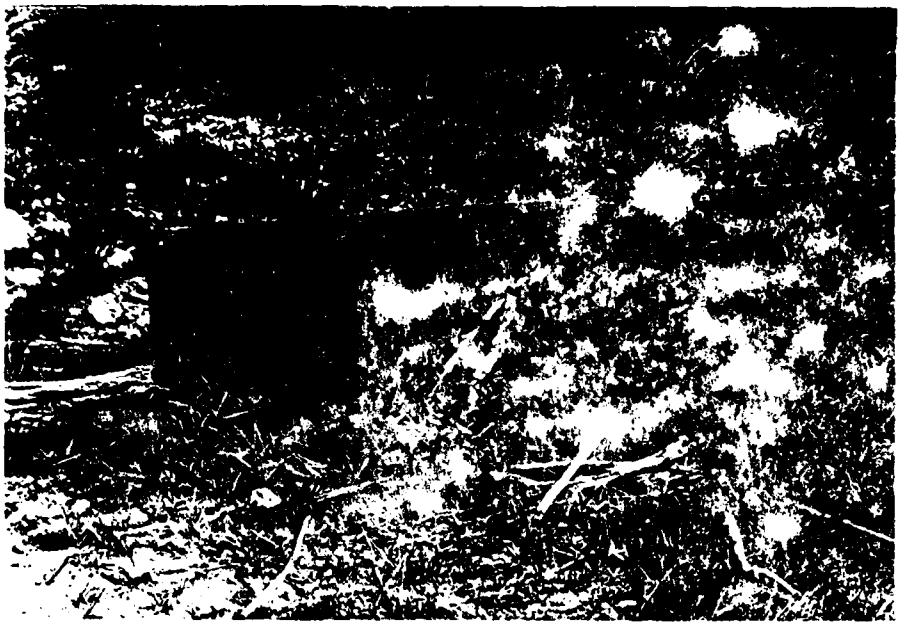


PHOTO 3 Sideview of Principal Spillway Structure

PHOTO 4 View of Right Abutment shows Monitoring and Recording Structure. The Emergency Spillway Entrance is Visible to the Right of the Structure.

PHOTO 5 Emergency Spillway Exit Channel

PHOTO 6 Right Abutment Showing Bedrock

APPENDIX A

HYDROLOGIC AND HYDRAULIC ANALYSIS METHODOLOGY

HYDROLOGIC AND HYDRAULIC ANALYSIS METHODOLOGY

1. The hydrologic analysis used in development of the overtopping potential is based on applying a hypothetical storm to a unit hydrograph to obtain the inflow hydrograph for a reservoir routing. The Probable Maximum Precipitation is derived and determined from regional charts prepared by the National Weather Service in "Hydrometeorological Report No. 33." Reduction factors have not been applied. A 24-hour storm duration is assumed with the total rainfall depth distributed over 6-hour periods in accordance with procedures outlined in EM 1110-2-1411 (SPF Determination). The maximum 6-hour rainfall period is then distributed to hourly increments by the same criteria. Within-the-hour distribution is based upon NOAA Technical Memorandum NWS HYDRO-35. The nonpeak 6-hour rainfall periods are distributed uniformly. All distributed values are arranged in a critical sequence by the SPF criteria. The final inflow hydrograph is produced by utilizing the Soil Conservation Service dimensionless unit hydrograph using Hydrologic Soils Group "B", Antecedent Moisture Condition III, and SCS CN 82 used to determine rainfall excess.

Lag time was estimated using methods outlined in "Design of Small Dams", by the United States Department of The Interior, Bureau of Reclamation. Using this source, lag time is taken as 60% of the time of concentration.

Time of concentration was estimated utilizing methods outlined in the source quoted above, supplemented by data obtained during field investigation. The results of the field investigation and the computations indicated that a time of 30 minutes was appropriate. For this lake, a lag time of 0.3 hours was therefore selected.

2. The reservoir routing is accomplished by using Modified Puls routing techniques wherein the flood hydrograph is routed through lake storage. Hydraulic capacities of the outlet works, spillway, and crest of dam are used as outlet controls in the routing. Storage in the pool area is defined by an elevation-storage capacity curve. The hydraulic capacity of the outlet works, spillway, and top of dam are defined by elevation-discharge curves.

3. Dam overtopping analysis has been conducted by hydrologic methods for this dam and lake. This computation determines the percentage of the PMF hydrograph that the reservoir can contain without the dam being overtopped. An output summary in the hydrologic appendix displays this information as well as other characteristics of the simulated dam overtopping.

4. The above methodology has been accomplished for this report using the systemized computer program HEC-1 (Dam Safety Version), July 1978, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California. The numeric parameters estimated for this site are listed in the attached computer printout. Definitions of these variables are contained in the "User's Manual" for the computer program.

5. The inflow hydrograph was routed through the reservoir using HEC-1's Modified Puls option. Releases were calculated for: 1) the principal spillway, 2) the overflow spillway, and 3) the flow over the top of the dam. These releases were then combined at each of their respective elevations.

Flow through the drop structure and pipe outlet at the principal spillway was obtained by considering the 36" diameter drop pipe as a weir for the initial or lower stages and as an orifice for subsequent higher stages.

For the weir conditions.

$$Q = CL(H)^{1.5}$$

where: C = Varies with head as outlined in "Handbook of Hydraulics" by Horace Williams King, revised by Ernest F. Brater.

L = Length in feet = 9.42.

H = Head of water in feet (varies with water surface)

Q = Discharge in cfs

For the orifice condition:

$$Q = CA\ (2g.H)^{\frac{1}{2}}$$

Where:

C = 0.60

A = Area of 36" diameter pipes = 7.069 $Ft.^2$

G = Acceleration due to gravity = 32.2 $ft/_{(sec)^2}$

H = Head in feet (varies with water surface).

Q = Discharge in cfs.

Flow through the overflow spillway and over the top of dam was calculated using the weir flow equation:

$$Q = CL(H)^{1.5}$$

where: C = Varies with head as outlined in "Handbook of Hydraulics" by Horace Williams King, revised by Ernest F. Brater.

L = Length in feet (varies with water surface)

H = Head of water in feet (varies with water surface)

Q = Discharge in cfs

```
**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  3 AUG 78
**********
    1              A1                          ASARCO  LAKE
    2              A2                         NOV. 30, 1978
    3              A3                         MO. INV. NO. 30216
    4              R    2RA      -0       5       -0       -0       -0       -0       -0       -4       -0
    5              B1     5
    6              J      1        6       1
    7              J1   .25      .30     .35      .40      .50     1.00
    8              K      0  INFLOW                                    3
    9              M      1        2     .76                         1                          1
   10              P              26.5     100      120      130
   11              T                                                          -1      -82                .05
   12              W2               .30
   13              X   1.52       -.1       3
   14              K      1 ROUTING                                   2        2
   15              Y                                        1        1
   16              Y1     1                                                          -928.7       -1
   17              Y4 928.7    929.0    929.5    930.0    930.5    931.0    931.5    932.0    932.5    933.0
   18              Y4 933.5    934.0    934.5    935.0    935.5    936.0    936.5    937.0    937.5    938.0
   19              Y5     0     3.92    18.13    29.21    34.25    38.71    42.72    46.37    93.88   193.00
   20              Y5331.36   458.53   471.96  1211.92  2395.13  3874.48  5614.60  7676.06  9989.36 12531.3
   21              $S     0    18.32    48.86    79.39   113.06   147.03   181.30   215.86   250.73   285.89
   22              $S321.35   357.11   393.17   429.53   466.18   503.13   540.38   577.93   615.78   653.93
   23              $E 928.7    929.0    929.5    930.0    930.5    931.0    931.5    932.0    932.5    933.0
   24              $E 933.5    934.0    934.5    935.0    935.5    936.0    936.5    937.0    937.5    938.0
   25              $$ 928.7
   26              $D 934.0
   27              K     99
```

COMPUTER INPUT DATA

FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 3 AUG 78

RUN DATE= 12/07/78.
TIME= 10.05.30.

ASARCO LAKE
NOV. 30, 1978
MO. INV. NO. 30216

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
288	-0	5	-0	-0	-0	-0	-0	-4	-0
			JOPER	NWT	LROPT	TRACE			
			5	-0	-0	-0			

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 6 LRTIO= 1
RTIOS= .25 .30 .35 .40 .50 1.00

SUB-AREA RUNOFF COMPUTATION

	ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
	INFLOW	0	-0	-0	-0	3	-0	-0	-0

HYDROGRAPH DATA

	IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
	1	2	.76	-0.00	.76	1.00	-0.000	-0	1	-0

PRECIP DATA

	SPFE	PMS	R6	R12	R24	R48	R72	R96
	-0.00	26.50	100.00	120.00	130.00	-0.00	-0.00	-0.00

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
-0	-0.00	-0.00	1.00	-0.00	-0.00	1.00	-1.00	-82.00	-0.00	.05

CURVE NO = -82.00 WETNESS = -1.00 EFFECT CN = 82.00

UNIT HYDROGRAPH DATA
TC= -0.00 LAG= .30

RECESSION DATA
STRTQ= 1.52 QRCSN= -.10 RTIOR= 3.00

UNIT HYDROGRAPH 20 END OF PERIOD ORDINATES, TC= -0.00 HOURS, LAG= .30 VOL= 1.00

150.	485.	920.	1074.	987.	772.	490.	328.	225.	150.
102.	68.	45.	31.	21.	14.	10.	7.	4.	1.

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	.00	.01	1.	1.01	12.05	145	.22	.21	.01	421.
1.01	.10	2	.01	.00	.01	2.	1.01	12.10	146	.22	.21	.01	489.
1.01	.15	3	.01	.00	.01	3.	1.01	12.15	147	.22	.21	.01	416.

INPUT UNIT HYDROGRAPH

1.01	.20	4	.01	.00	.01	3.	1.01	12.20	148	.22	.21	.01	765.
1.01	.25	5	.01	.00	.01	4.	1.01	12.25	149	.22	.21	.01	903.
1.01	.30	6	.01	.00	.01	4.	1.01	12.30	150	.22	.21	.01	1012.
1.01	.35	7	.01	.00	.01	4.	1.01	12.35	151	.22	.21	.01	1082.
1.01	.40	8	.01	.00	.01	4.	1.01	12.40	152	.22	.21	.01	1130.
1.01	.45	9	.01	.00	.01	5.	1.01	12.45	153	.22	.21	.01	1164.
1.01	.50	10	.01	.00	.01	5.	1.01	12.50	154	.22	.21	.01	1188.
1.01	.55	11	.01	.00	.01	5.	1.01	12.55	155	.22	.21	.01	1205.
1.01	1.00	12	.01	.00	.01	5.	1.01	13.00	156	.22	.21	.01	1217.
1.01	1.05	13	.01	.00	.01	5.	1.01	13.05	157	.26	.25	.01	1232.
1.01	1.10	14	.01	.00	.01	5.	1.01	13.10	158	.26	.26	.01	1260.
1.01	1.15	15	.01	.00	.01	5.	1.01	13.15	159	.26	.26	.01	1304.
1.01	1.20	16	.01	.00	.01	5.	1.01	13.20	160	.26	.26	.01	1354.
1.01	1.25	17	.01	.00	.01	5.	1.01	13.25	161	.26	.26	.01	1400.
1.01	1.30	18	.01	.00	.01	5.	1.01	13.30	162	.26	.26	.01	1437.
1.01	1.35	19	.01	.00	.01	5.	1.01	13.35	163	.26	.26	.01	1460.
1.01	1.40	20	.01	.00	.01	4.	1.01	13.40	164	.26	.26	.01	1477.
1.01	1.45	21	.01	.00	.01	4.	1.01	13.45	165	.26	.26	.01	1489.
1.01	1.50	22	.01	.00	.01	4.	1.01	13.50	166	.26	.26	.01	1497.
1.01	1.55	23	.01	.00	.01	4.	1.01	13.55	167	.26	.26	.01	1504.
1.01	2.00	24	.01	.00	.01	4.	1.01	14.00	168	.26	.26	.01	1508.
1.01	2.05	25	.01	.00	.01	4.	1.01	14.05	169	.33	.32	.01	1522.
1.01	2.10	26	.01	.00	.01	4.	1.01	14.10	170	.33	.32	.01	1556.
1.01	2.15	27	.01	.00	.01	4.	1.01	14.15	171	.33	.32	.01	1618.
1.01	2.20	28	.01	.00	.01	4.	1.01	14.20	172	.33	.32	.01	1690.
1.01	2.25	29	.01	.00	.01	4.	1.01	14.25	173	.33	.32	.01	1756.
1.01	2.30	30	.01	.00	.01	4.	1.01	14.30	174	.33	.33	.01	1808.
1.01	2.35	31	.01	.00	.01	4.	1.01	14.35	175	.33	.33	.01	1842.
1.01	2.40	32	.01	.00	.01	4.	1.01	14.40	176	.33	.33	.01	1865.
1.01	2.45	33	.01	.00	.01	5.	1.01	14.45	177	.33	.33	.01	1881.
1.01	2.50	34	.01	.00	.01	5.	1.01	14.50	178	.33	.33	.01	1892.
1.01	2.55	35	.01	.00	.01	6.	1.01	14.55	179	.33	.33	.00	1900.
1.01	3.00	36	.01	.00	.01	6.	1.01	15.00	180	.33	.33	.00	1906.
1.01	3.05	37	.01	.00	.01	7.	1.01	15.05	181	.20	.20	.00	1891.
1.01	3.10	38	.01	.00	.01	8.	1.01	15.10	182	.40	.40	.01	1862.
1.01	3.15	39	.01	.00	.01	9.	1.01	15.15	183	.40	.40	.01	1843.
1.01	3.20	40	.01	.00	.01	10.	1.01	15.20	184	.60	.60	.01	1920.
1.01	3.25	41	.01	.00	.01	11.	1.01	15.25	185	.70	.70	.01	2121.
1.01	3.30	42	.01	.00	.01	12.	1.01	15.30	186	1.71	1.69	.02	2601.
1.01	3.35	43	.01	.00	.01	13.	1.01	15.35	187	2.82	2.80	.02	3647.
1.01	3.40	44	.01	.00	.01	14.	1.01	15.40	188	1.11	1.10	.01	5205.
1.01	3.45	45	.01	.00	.01	15.	1.01	15.45	189	.70	.70	.00	6697.
1.01	3.50	46	.01	.00	.01	16.	1.01	15.50	190	.60	.60	.00	7294.
1.01	3.55	47	.01	.00	.01	16.	1.01	15.55	191	.40	.40	.00	7014.
1.01	4.00	48	.01	.00	.01	17.	1.01	16.00	192	.40	.40	.00	6150.
1.01	4.05	49	.01	.00	.01	18.	1.01	16.05	193	.31	.31	.00	5069.
1.01	4.10	50	.01	.00	.01	19.	1.01	16.10	194	.31	.31	.00	4197.
1.01	4.15	51	.01	.00	.01	20.	1.01	16.15	195	.31	.31	.00	3510.
1.01	4.20	52	.01	.00	.01	21.	1.01	16.20	196	.31	.31	.00	2979.
1.01	4.25	53	.01	.00	.01	21.	1.01	16.25	197	.31	.31	.00	2605.
1.01	4.30	54	.01	.00	.01	22.	1.01	16.30	198	.31	.31	.00	2341.
1.01	4.35	55	.01	.00	.01	23.	1.01	16.35	199	.31	.31	.00	2166.
1.01	4.40	56	.01	.00	.01	24.	1.01	16.40	200	.31	.31	.00	2050.
1.01	4.45	57	.01	.00	.01	24.	1.01	16.45	201	.31	.31	.00	1972.
1.01	4.50	58	.01	.00	.01	25.	1.01	16.50	202	.31	.31	.00	1919.
1.01	4.55	59	.01	.00	.01	26.	1.01	16.55	203	.31	.31	.00	1884.
1.01	5.00	60	.01	.00	.01	26.	1.01	17.00	204	.31	.31	.00	1859.
1.01	5.05	61	.01	.01	.01	27.	1.01	17.05	205	.24	.24	.00	1830.
1.01	5.10	62	.01	.01	.01	28.	1.01	17.10	206	.24	.24	.00	1783.
1.01	5.15	63	.01	.01	.01	28.	1.01	17.15	207	.24	.24	.00	1714.
1.01	5.20	64	.01	.01	.01	29.	1.01	17.20	208	.24	.24	.00	1640.
1.01	5.25	65	.01	.01	.01	30.	1.01	17.25	209	.24	.24	.00	1573.
1.01	5.30	66	.01	.01	.01	30.	1.01	17.30	210	.24	.24	.00	1522.
1.01	5.35	67	.01	.01	.01	31.	1.01	17.35	211	.24	.24	.00	1489.
1.01	5.40	68	.01	.01	.01	32.	1.01	17.40	212	.24	.24	.00	1467.

INPUT UNIT HYDROGRAPH

1.01	5.50	70	.01	.01	.01	33.	1.01	17.50	214	.24	.24	.00	1443.
1.01	5.55	71	.01	.01	.01	33.	1.01	17.55	215	.24	.24	.00	1436.
1.01	6.00	72	.01	.01	.01	34.	1.01	18.00	216	.24	.24	.00	1432.
1.01	6.05	73	.07	.03	.04	38.	1.01	18.05	217	.02	.02	.00	1396.
1.01	6.10	74	.07	.03	.04	52.	1.01	18.10	218	.02	.02	.00	1287.
1.01	6.15	75	.07	.04	.04	77.	1.01	18.15	219	.02	.02	.00	1083.
1.01	6.20	76	.07	.04	.04	109.	1.01	18.20	220	.02	.02	.00	846.
1.01	6.25	77	.07	.04	.03	140.	1.01	18.25	221	.02	.02	.00	694.
1.01	6.30	78	.07	.04	.03	167.	1.01	18.30	222	.02	.02	.00	622.
1.01	6.35	79	.07	.04	.03	187.	1.01	18.35	223	.02	.02	.00	557.
1.01	6.40	80	.07	.04	.03	204.	1.01	18.40	224	.02	.02	.00	499.
1.01	6.45	81	.07	.05	.03	219.	1.01	18.45	225	.02	.02	.00	447.
1.01	6.50	82	.07	.05	.03	231.	1.01	18.50	226	.02	.02	.00	401.
1.01	6.55	83	.07	.05	.03	242.	1.01	18.55	227	.02	.02	.00	359.
1.01	7.00	84	.07	.05	.03	251.	1.01	19.00	228	.02	.02	.00	322.
1.01	7.05	85	.07	.05	.02	260.	1.01	19.05	229	.02	.02	.00	288.
1.01	7.10	86	.07	.05	.02	268.	1.01	19.10	230	.02	.02	.00	258.
1.01	7.15	87	.07	.05	.02	275.	1.01	19.15	231	.02	.02	.00	231.
1.01	7.20	88	.07	.05	.02	281.	1.01	19.20	232	.02	.02	.00	207.
1.01	7.25	89	.07	.05	.02	288.	1.01	19.25	233	.02	.02	.00	186.
1.01	7.30	90	.07	.05	.02	293.	1.01	19.30	234	.02	.02	.00	166.
1.01	7.35	91	.07	.05	.02	299.	1.01	19.35	235	.02	.02	.00	149.
1.01	7.40	92	.07	.05	.02	304.	1.01	19.40	236	.02	.02	.00	134.
1.01	7.45	93	.07	.06	.02	309.	1.01	19.45	237	.02	.02	.00	129.
1.01	7.50	94	.07	.06	.02	313.	1.01	19.50	238	.02	.02	.00	129.
1.01	7.55	95	.07	.06	.02	317.	1.01	19.55	239	.02	.02	.00	129.
1.01	8.00	96	.07	.06	.02	321.	1.01	20.00	240	.02	.02	.00	129.
1.01	8.05	97	.07	.06	.02	325.	1.01	20.05	241	.02	.02	.00	129.
1.01	8.10	98	.07	.06	.02	329.	1.01	20.10	242	.02	.02	.00	129.
1.01	8.15	99	.07	.06	.01	332.	1.01	20.15	243	.02	.02	.00	129.
1.01	8.20	100	.07	.06	.01	336.	1.01	20.20	244	.02	.02	.00	129.
1.01	8.25	101	.07	.06	.01	339.	1.01	20.25	245	.02	.02	.00	129.
1.01	8.30	102	.07	.06	.01	342.	1.01	20.30	246	.02	.02	.00	129.
1.01	8.35	103	.07	.06	.01	344.	1.01	20.35	247	.02	.02	.00	129.
1.01	8.40	104	.07	.06	.01	347.	1.01	20.40	248	.02	.02	.00	129.
1.01	8.45	105	.07	.06	.01	350.	1.01	20.45	249	.02	.02	.00	129.
1.01	8.50	106	.07	.06	.01	352.	1.01	20.50	250	.02	.02	.00	129.
1.01	8.55	107	.07	.06	.01	355.	1.01	20.55	251	.02	.02	.00	129.
1.01	9.00	108	.07	.06	.01	357.	1.01	21.00	252	.02	.02	.00	129.
1.01	9.05	109	.07	.06	.01	359.	1.01	21.05	253	.02	.02	.00	129.
1.01	9.10	110	.07	.06	.01	361.	1.01	21.10	254	.02	.02	.00	129.
1.01	9.15	111	.07	.06	.01	363.	1.01	21.15	255	.02	.02	.00	129.
1.01	9.20	112	.07	.06	.01	365.	1.01	21.20	256	.02	.02	.00	129.
1.01	9.25	113	.07	.06	.01	367.	1.01	21.25	257	.02	.02	.00	129.
1.01	9.30	114	.07	.06	.01	368.	1.01	21.30	258	.02	.02	.00	129.
1.01	9.35	115	.07	.06	.01	370.	1.01	21.35	259	.02	.02	.00	129.
1.01	9.40	116	.07	.06	.01	372.	1.01	21.40	260	.02	.02	.00	129.
1.01	9.45	117	.07	.06	.01	373.	1.01	21.45	261	.02	.02	.00	129.
1.01	9.50	118	.07	.06	.01	375.	1.01	21.50	262	.02	.02	.00	129.
1.01	9.55	119	.07	.06	.01	376.	1.01	21.55	263	.02	.02	.00	129.
1.01	10.00	120	.07	.07	.01	378.	1.01	22.00	264	.02	.02	.00	129.
1.01	10.05	121	.07	.07	.01	379.	1.01	22.05	265	.02	.02	.00	129.
1.01	10.10	122	.07	.07	.01	380.	1.01	22.10	266	.02	.02	.00	129.
1.01	10.15	123	.07	.07	.01	382.	1.01	22.15	267	.02	.02	.00	129.
1.01	10.20	124	.07	.07	.01	383.	1.01	22.20	268	.02	.02	.00	129.
1.01	10.25	125	.07	.07	.01	384.	1.01	22.25	269	.02	.02	.00	129.
1.01	10.30	126	.07	.07	.01	385.	1.01	22.30	270	.02	.02	.00	129.
1.01	10.35	127	.07	.07	.01	386.	1.01	22.35	271	.02	.02	.00	129.
1.01	10.40	128	.07	.07	.01	387.	1.01	22.40	272	.02	.02	.00	129.
1.01	10.45	129	.07	.07	.01	388.	1.01	22.45	273	.02	.02	.00	129.
1.01	10.50	130	.07	.07	.01	389.	1.01	22.50	274	.02	.02	.00	129.
1.01	10.55	131	.07	.07	.01	390.	1.01	22.55	275	.02	.02	.00	129.
1.01	11.00	132	.07	.07	.01	391.	1.01	23.00	276	.02	.02	.00	129.
1.01	11.05	133	.07	.07	.01	392.	1.01	23.05	277	.02	.02	.00	129.
1.01	11.10	134	.07	.07	.01	393.	1.01	23.10	278	.02	.02	.00	129.

INPUT UNIT HYDROGRAPH

INC.

1.01	11.20	136	.07	.07	.01	394.	1.01	23.20	280	.02	.02	.00	129.
1.01	11.25	137	.07	.07	.01	395.	1.01	23.25	281	.02	.02	.00	129.
1.01	11.30	138	.07	.07	.01	396.	1.01	23.30	282	.02	.02	.00	129.
1.01	11.35	139	.07	.07	.01	397.	1.01	23.35	283	.02	.02	.00	129.
1.01	11.40	140	.07	.07	.01	397.	1.01	23.40	284	.02	.02	.00	129.
1.01	11.45	141	.07	.07	.01	398.	1.01	23.45	285	.02	.02	.00	129.
1.01	11.50	142	.07	.07	.01	399.	1.01	23.50	286	.02	.02	.00	129.
1.01	11.55	143	.07	.07	.01	399.	1.01	23.55	287	.02	.02	.00	129.
1.01	12.00	144	.07	.07	.01	400.	1.02	0.00	288	.02	.02	.00	129.
									SUM	34.45	32.07	2.38	190063.
										(875.)	(815.)	(60.)	(5381.98)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	7294.	2100.	660.	660.	190029.
CMS	207.	59.	19.	19.	5381.
INCHES		25.71	32.30	32.30	32.30
MM		652.93	820.54	820.54	820.54
AC-FT		1041.	1309.	1309.	1309.
THOUS CU M		1285.	1614.	1614.	1614.

HYDROGRAPH AT STAINFLOW FOR PLAN 1, RTIO 1

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	1824.	525.	165.	165.	47507.
CMS	52.	15.	5.	5.	1345.
INCHES		6.43	8.08	8.08	8.08
MM		163.23	205.13	205.13	205.13
AC-FT		260.	327.	327.	327.
THOUS CU M		321.	404.	404.	404.

HYDROGRAPH AT STAINFLOW FOR PLAN 1, RTIO 2

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	2188.	630.	198.	198.	57009.
CMS	62.	18.	6.	6.	1614.
INCHES		7.71	9.69	9.69	9.69
MM		195.88	246.16	246.16	246.16
AC-FT		312.	393.	393.	393.
THOUS CU M		385.	484.	484.	484.

HYDROGRAPH AT STAINFLOW FOR PLAN 1, RTIO 3

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	2553.	735.	231.	231.	66510.
CMS	72.	21.	7.	7.	1883.
INCHES		9.00	11.31	11.31	11.31
MM		228.53	287.19	287.19	287.19
AC-FT		364.	458.	458.	458.
THOUS CU M		450.	565.	565.	565.

INPUT UNIT HYDROGRAPH

HYDROGRAPH AT STAINFLOW FOR PLAN 1, RTIO 4

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	2918.	840.	264.	264.	76011.
CMS	83.	24.	7.	7.	2152.
INCHES		10.28	12.92	12.92	12.92
			328.21	328.21	328.21

END-OF-PERIOD HYDROGRAPH ORDINATES

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	928.70	928.70	934.00
STORAGE	0.	0.	357.
OUTFLOW	0.	0.	459.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.25	932.83	0.00	274.	160.	0.00	18.50	0.00
.30	933.36	0.00	311.	292.	0.00	18.25	0.00
.35	933.82	0.00	344.	413.	0.00	18.25	0.00
.40	934.36	.36	383.	468.	2.75	18.25	0.00
.50	934.89	.89	422.	1055.	4.08	16.58	0.00
1.00	936.48	2.48	539.	5534.	6.50	16.08	0.00

CONCRETE SPILLWAY NOTES


DATE
IL ME